

CLAIMS

1. A method for frequency-offset error determination, comprising the steps of:

receiving a string composed of a same basic constituent repeated ten times, where a basic constituent is generated from a sequence, defined in the frequency domain, containing QPSK-like modulated elements;

sampling said string to collect a plurality of measurements each including two of said basic constituents;

accounting for all measured differences amongst said plurality of samples as being solely attributable to a common frequency-offset error; and

correcting for said common frequency-offset error in later digital signal processing.

2. The method of Claim 1, wherein:

the step of sampling includes skipping a first few of said repeating QPSK symbols before a first measurement is taken.

3. The method of Claim 1, wherein:

the step of sampling includes measuring said string of repeating QPSK-like modulated elements three times to obtain $s_1(n)$, $s_2(n)$, and $s_3(n)$; ; and

the step of accounting sets up for solution a matrix,

$$R = Z^H Z \quad \text{with,}$$

$$Z = \begin{bmatrix} s_1(n) & s_2(n) & s_3(n) \end{bmatrix}$$

$$s_1(n) = \sigma_1(n) + \eta_1(n)$$

$$s_2(n) = \sigma_2(n) + \eta_2(n)$$

$$s_3(n) = \sigma_3(n) + \eta_3(n)$$

$$\sigma_1(n) = A e^{j 2 \pi \frac{v}{F_c} (n + j \Phi(n)) + j \phi}$$

$$\sigma_2(n) = A e^{j 2 \pi \frac{v}{F_c} (n + N) + j \Phi(n + N) + j \phi} = e^{j 2 \pi \frac{v}{F_c} N} \sigma_1(n)$$

$$\sigma_3(n) = A e^{j 2 \pi \frac{v}{F_c} (n + 2N) + j \Phi(n + 2N) + j \phi} = e^{j 2 \pi \frac{v}{F_c} 2N} \sigma_1(n) = e^{j 4 \pi \frac{v}{F_c} N} \sigma_1(n)$$

and that can be expanded to,

$$R = \begin{bmatrix} MA^2 + \gamma_{1,1}^M & MA^2 e^{j2\pi \frac{v}{F_s} N} + \gamma_{1,2}^M & MA^2 e^{j4\pi \frac{v}{F_s} N} + \gamma_{1,3}^M \\ MA^2 e^{-j2\pi \frac{v}{F_s} N} + \bar{\gamma}_{1,2}^M & MA^2 + \gamma_{2,2}^M & MA^2 e^{j2\pi \frac{v}{F_s} N} + \gamma_{2,3}^M \\ MA^2 e^{-j4\pi \frac{v}{F_s} N} + \bar{\gamma}_{1,3}^M & MA^2 e^{-j2\pi \frac{v}{F_s} N} + \bar{\gamma}_{2,3}^M & MA^2 + \gamma_{3,3}^M \end{bmatrix}$$

5 with:

$$\gamma_{k,l}^M = \sum_{n=1}^M \eta_k(n) \eta_l^*(n)$$

wherein, in the absence of noise, R is rank 1 and decomposes as,

$$R = \sum_{n=1}^K \lambda_n a_n a_n^H$$

$$-x = \sum_{m=1}^K \gamma_m a_m$$

4. The method of Claim 3, wherein:

the step of accounting recognizes any received signals is adversely affected by additive white Gaussian noise and multi-path interference, and determines R's maximum eigenvector in a first step followed by an iterative method with two iterations for a pseudo rank one matrix, and generally conforms to, expressing R and any vector $x \in C^K$ using the eigenvector basis,

$$R = \sum_{n=1}^K \lambda_n a_n a_n^H$$

$$x = \sum_{m=1}^K \gamma_m a_m$$

wherein, the vector matrix products are computed by,

$$x_1 = x_0 R = \sum_{m=1}^K \gamma_m a_m \sum_{n=1}^K \lambda_n a_n^H a_n = \sum_{m=1}^K \sum_{n=1}^K \gamma_m \lambda_n (a_m a_n^H) a_n = \sum_{m,n=1}^K \gamma_m \lambda_n \delta_{m,n} a_n = \sum_{m=1}^K \gamma_m \lambda_m a_m$$

$$x_2 = x_1 R = \sum_{m=1}^K \gamma_m \lambda_m a_m \sum_{n=1}^K \lambda_n a_n^H a_n = \sum_{m=1}^K \sum_{n=1}^K \gamma_m \lambda_m \lambda_n (a_m a_n^H) a_n = \sum_{m,n=1}^K \gamma_m \lambda_m \lambda_n \delta_{m,n} a_n = \sum_{m=1}^K \gamma_m \lambda_m^2 a_m$$

and this iterative operation is repeated up to x_k ,

$$x_k = x_{k-1} R = \sum_{m=1}^K \gamma_m \lambda_m^{k-1} a_m \sum_{n=1}^K \lambda_n a_n^H a_n = \sum_{m=1}^K \sum_{n=1}^K \gamma_m \lambda_m^{k-1} \lambda_n (a_m a_n^H) a_n = \sum_{m,n=1}^K \gamma_m \lambda_m^{k-1} \lambda_n \delta_{m,n} a_n = \sum_{m=1}^K \gamma_m \lambda_m^k a_m$$

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5. The method of Claim 3, wherein:

the step of accounting assumes R to have pseudo rank one, and the spectrum of eigenvalues is such that $\lambda_1 = \lambda_1 \gg \lambda_2, \lambda_3, \dots, \lambda_K$, so x_k rapidly converge to $\lambda_1 a_1$ as k increases.

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6. The method of Claim 1, further comprising the steps of:

computing $f(\mu)$ for sixty-four equally spaced values of μ ranging from 0 to 208.33kHz once a maximum eigenvector is available; and identifying a bulky peak which provides $\hat{\nu}$, the frequency offset estimate.

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7. The method of Claim 1, further comprising the steps of:

determining the sign of the imaginary part of the second component of the dominant eigenvector;

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based upon the sign of the imaginary part of the second component of the dominant eigenvector, conjugate (or not) 64 pre-stored steering vectors which span possible frequency offsets from 0 to 208.33kHz;

computing an objective function, $f(\nu)$ over frequency offset in the range of 0 to 208.33kHz; when $\mu = \nu$ (true frequency offset), then a maximum of occurs;

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finding the index of the maximum of $f(\mu)$;

using this index as an element into a pre-stored lookup table consisting of $e^{j2\pi(\frac{\mu_i}{F_c})}$ for all μ_i from 0 to 208.33kHz in 64 increments; where single values of the complex exponential are stored for all positive frequency offsets;

5 let an index of the maximum of $f(\mu) = j$;

then, a value retrieved from the table is $e^{j2\pi(\frac{\mu_j}{F_c})}$;

based upon a sign of the imaginary part of a second component of a dominant eigenvector, conjugate this value to get a proper starting point for a frequency-correcting cisoid;

10 wherein remaining elements of said frequency-correcting cisoid are generated as follows:

$e^{j2\pi(\frac{\mu_x}{F_c})}$ is retrieved from a table and stored to memory at memory location X;

loading a resulting value from memory, multiplied with itself, producing

$$e^{j2\pi(\frac{\mu_x}{F_c})2};$$

storing a resulting value to memory location X+1;

(vector) loading the two values of the correction cisoid from memory location X into the processor;

20 wherein a last value of this vector is multiplied by the entire vector to produce next samples in a correction cisoid;

storing these two values to memory location X+2.

$$\begin{bmatrix} e^{j2\pi(\frac{\mu_x}{F_c})3} & e^{j2\pi(\frac{\mu_x}{F_c})4} \end{bmatrix} = e^{j2\pi(\frac{\mu_x}{F_c})2} * \begin{bmatrix} e^{j2\pi(\frac{\mu_x}{F_c})} & e^{j2\pi(\frac{\mu_x}{F_c})2} \end{bmatrix};$$

25 Reloading this vector into the processor starting at memory location X with length=4; and repeating this procedure 4 more times to obtain a correction cisoid.